VOLUME 85 NO. CO1
FEBRUARY 1959

JOURNAL of the

Construction Division

PROCEEDINGS OF THE

AMERICAN SOCIETY OF CIVIL ENGINEERS

VOL. 85 CO1 ASCE CONSTRUCTION JOURNAL

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1. Titles should have a length not exceeding 50 characters and spaces.

2. A 50-word summary should accompany the paper.

3. The manuscript (a ribbon copy and two copies) should be double-spaced on one side of 8½-in. by 11-in. paper. Papers that were originally prepared for oral presentation must be rewritten into the third person before being submitted.

4. The author's full name, Society membership grade, and footnote reference stating present employment should appear on the first page of the paper.

5. Mathematics are reproduced directly from the copy that is submitted. Because of this, it is necessary that capital letters be drawn, in black ink, ⅛-in. high (with all other symbols and characters in the proportions dictated by standard drafting practice) and that no line of mathematics be longer than 6½-in. Ribbon copies of typed equations may be used but they will be proportionately smaller on the printed version.

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8. Papers should average about 12,000 words in length and should be no longer than 18,000 words. As an approximation, each full page of typed text, table, or illustration is the equivalent of 300 words.

Further information concerning the preparation of technical papers is contained in the "Technical Publications Handbook" which can be obtained from the Society.

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Journal of the
CONSTRUCTION DIVISION
Proceedings of the American Society of Civil Engineers

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ENGINEERING EDUCATION AND THE CONSTRUCTION INDUSTRY: THE INDUSTRY AND THE COLLEGES

D. W. Winkelman,[1] M. ASCE and C. R. Maar,[2] A.M. ASCE

FOREWORD

Construction is this nation's largest single industry. Its 1957 dollar volume was 47 billions of dollars, or 11 per cent of the gross national product, yet it is a large anamorphic thing with no organization and no plan. At that, it offers civil engineering a new area of opportunity, according to Oglesby, ". . . to regain its position among the professional and scientific fields."

At the roots of this point is the everlasting dichotomy between the construction industry and the institutions of higher learning which turn out civil engineers. This must be resolved before we can enter upon an era of true progress. The old days when "college-kids" had to stand in awe of the time-worn construction superintendents who came up through the school-of hard-knocks are fortunately coming to an end. Numbered also are the days of wastefulness caused by hyper designs from those devoid of any idea of what problems a field man faces, trying to construct those didactic details.

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1. Pres. D. W. Winkelman Co., Inc., Syracuse, N. Y.
2. Engr. D. W. Winkelman Co., Inc., Syracuse, N. Y.

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M. D. Morris, M. ASCE
Chairman, Construction Division
Committee on Publications

ABSTRACT

The engineering college can be a major influence on the end product of the engineer it turns out for the construction industry. The man need not necessarily be a scholar, but he must understand the basic things and the language and know practicalities. He also must understand the humanities and must have some practical working knowledge of the tools at hand for him. This can be obtained in the colleges and by working in the field between times.

Let's first consider what the construction industry ultimately expects of its Engineers. Some of this end product is not the primary concern of the college, but the college is or can be a major influence.

The man in question need not necessarily be a scholar. Design is not a primary requirement. He must understand the basics of design, talk the language and, most important, know practical design from impractical design. From the scholarly side of him the industry hopes to extract a dynamic, flexible thinker. A man who can adjust his mind to a constant kaleidoscope of problems in equipment applications; production; costs; making the design a

reality; and most important, the problem of personnel relations.

This brings up a very important facet of this ultimate Engineer. He must have learned somewhere how to get along with others. Sometimes, this relationship is under most difficult conditions. He must, quite often, get the very most out of his employees, due to time limitations and the competitive character of the industry. The relationship with labor unions is a difficult and trying experience that requires diplomacy. The relationship with contract owners and Design Engineers is a delicate one. Then there is the constant association with material salesmen, other contractors and fellow employees that brings to this man's desk new personalities with new problems daily.

The Construction Engineer is to the engineering profession what the general practioner is to medicine, in order to accomplish a result like the caissons for the Mackinac Bridge (Fig. 1), and it is to this degree that the colleges must train him. He must learn his design, his drafting, his surveying and the important functions of other engineering professions such as mechanical and electrical because he often works side by side with them. He must also learn psychology, public relations, public speaking and other liberal art subjects to give him sufficient background and confidence in his management duties. Finally, he must know cost accounting, finance and bookkeeping because these are the very core and the only score sheets available in one of the most highly competitive games going.

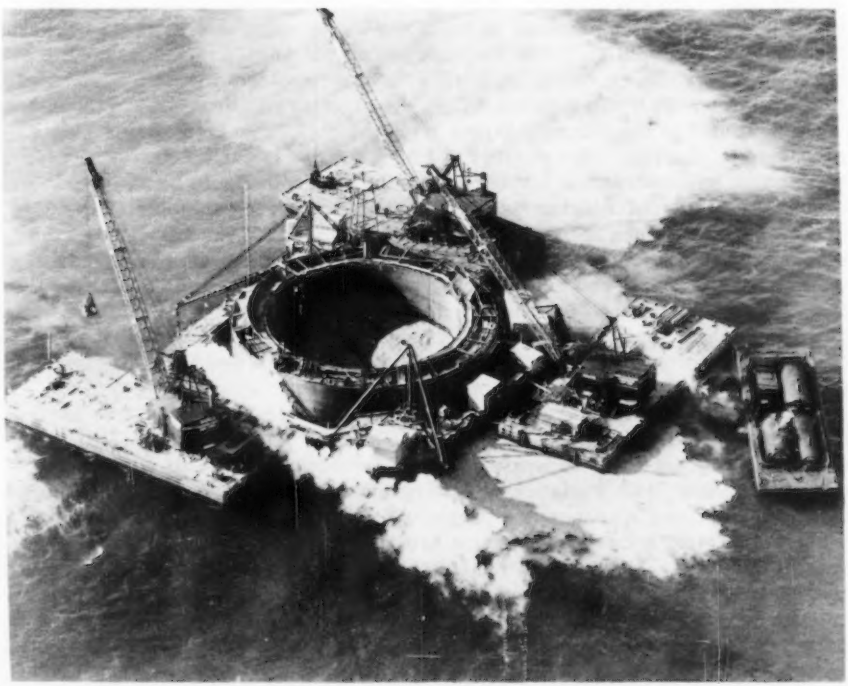

Fig. 1. — Mackinac Bridge Caissons.

So much for the theoretical expectations. Now, what practically can we expect the engineering colleges to teach the young constructor. The college can certainly provide the liberal arts background. This must be broad enough so he can associate properly his engineering status in societies total picture. The Cornell academic catalog words it very well when they say "An engineering career has its roots in science and technology, but in its breadth it touches many areas of human activity."

The college also must provide the technical background. With the courses in Physics, Chemistry, Mathematics, Mechanics, and so on there seems to be little disagreement as witness the comparison between Cornell's curriculum and that advocated by AGC's W. A. Klinger in the ENR of November 7, 1957. These are all the basic fundamentals and, of course, absolutely necessary.

Still further in the technical field are the courses that introduce the associated sciences and engineering professions; like Heat and Power, Electricity, and Geology, to mention a few. Because of the Civil Engineer's contact with many of these technicians, he should have some exposure. The normal four year college curriculum allows only a minimum of this.

Next are those subjects directly applicable to construction. Courses in equipment: evaluating types by production and application; Methods: covering various operations as earth moving, paving, tunneling, and water side construction; costs, quantities and estimating: showing how costs are the guide to each operation and the function of estimating to competitive bidding; and something on law and finance. Some colleges today give considerable time and effort in providing courses in all of the above mentioned criteria. Others feel that such specialization at the college level is perhaps unnecessary, but if the Engineer can enter the industry with these subjects already introduced to him, immediately his function within the structure is broader and deeper.

Now, what can the industry expect from the college to further this man's management function? He should have been offered opportunities to receive instruction in construction management. This course should be an introduction to the problems in supervising a construction project. Including the scheduling and purchasing of materials and equipment. The selection of employees, organization of the field office, payroll and cost control and maybe something on reports and accident prevention. A course in Economics would help. An introduction to Psychology might further his understanding and ability to control and organize men. There may be other courses that would broaden his outlook, but we probably have already exceeded the time limits imposed by a four year curriculum.

Is it feasible for the industry to expect an Engineer from college to have some experience? It would seem, in some areas, entirely possible that an informal program could be worked out in conjunction with local contractors that would allow Civil Engineering undergraduates, who have indicated through their programming that they are preparing themselves for a career in heavy construction, to work on construction projects as engineering technicians or even as laborers. More can be done than this, even: field trips could be arranged, preceded by orientation lectures, that would take an interested group to one or more projects and see the different operations and applications of equipment. These two methods of acquiring some experience may help to alleviate the on-the-job training that is required to familiarize the young Engineer with the required procedures.

It appears that we have covered about everything that comes to our mind in the academic sense. There is also the psychological side of the Engineer that in some instances can be a problem. Dr. J. R. Kilian, Jr. covers this very well in an article from the Engineer's Job Directory that is in most college recruiting offices. It is entitled "From Class Room to Plant" and points up the adjustment that most Engineers have to make when they move from Big-Man-on-Campus to Little-Man-in-Industry. It is especially true in these times where they are sought after during recruitment by many firms with fancy offers. Then when they do decide and settle down to the initial period of learning company policy and are assigned some rather routine duties for the time necessary for integration into the company structure they become restless and impatient, cannot yet see the challenge they so eagerly expect and often leave before they have even earned an important assignment. Perhaps somewhere along the academic way this necessary adjustment can be outlined and the point established that the young Engineer must, in the early stages, have faith in his employers experience and judgement that he will place him as is best for all concerned.

We hope with this that we have answered, at least from our viewpoint, the question "What the Construction Industry Should Have from Engineering Colleges?" On close comparison, what we here indicate as being required is probably very little different from what some of the colleges are already offering. This is especially true of Cornell whose five year program with all its electives is probably as well geared to America's largest industry, heavy construction, as any in the country.

Journal of the
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ENGINEERING EDUCATION AND THE CONSTRUCTION INDUSTRY: GRADUATES FOR WORK IN CONSTRUCTION

David A. Day,[1] A.M. ASCE

FOREWORD

Construction is this nation's largest single industry. Its 1957 dollar volume was 47 billions of dollars, or 11 per cent of the gross national product, yet it is a large anamorphic thing with no organization and no plan. At that, it offers civil engineering a new area of opportunity, according to Oglesby, ". . . to regain its position among the professional and scientific fields."

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1. Chmn., Civ. Eng. Dept., Univ. of Denver, Denver, Colo., previously in charge of the Construction Option in Div. Eng. at the Univ. of Illinois, Urbana, Ill.

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ABSTRACT

To point out what one civil engineering educator believes should be included in a modernized under-graduate curriculum to particularly benefit construction industry, this paper recommends that the coverage need not be all inclusive, yet it is desirable to study report writing, public speaking, basic sciences, engineering sciences, analysis, economics and management, and some humanities.

The construction industry is a gigantic, far-reaching activity in the United States and many other areas of the world. The scope and diversity of interests and occupations in it are difficult even for the student of business to comprehend. This was emphasized in the book Building, U.S.A. As a consequence there are undoubtedly many participants in the construction industry who do not appreciate some other segment that is contributing to the success of their occupation. This can be likened to the football fan who heaps all the glory on the running halfback unaware that without the linemen carrying out their assignments his running would draw no praise.

Civil Engineers are in large measure to be blamed for a lack of appreciation in the construction industry. The immediate reaction to this statement may be an abrupt question of why should engineers take such blame when they do not appear to be a part of this gangling industry. The idealogical engineer may argue that he is a professional man and therefore does not belong to any industry or commercial group. This sort of argument could be claimed by a majority of professional people among the three so-called learned professions. However, even some doctors and lawyers would have to admit that their work is so closely related to some commercial or industrial activity that they are really a part of that industry. The livelihood of the vast majority of engineers is so closely related and dependent on commercial or industrial activity, in the broadest sense, that they must recognize their vital part in some industry.

The Department of Commerce has for many years had all business or commercial activity within the United States divided into essentially half a dozen industries ranging from agriculture to manufacturing. Prior to World War II construction was evidently considered to be a form of manufacturing inspite of the inherent differences. However, since that revolutionary period of conflict and change, construction has increased so much in stature and contribution to national economy—even surpassing agriculture, the perennial forerunner—that the construction industry now is nationally recognized as a segment of activity by itself. As one of the main divisions of industrial activity in this country it must have the full cooperation of the engineers that serve it, just as the manufacturing, communication, and other industries do. Quite obviously civil engineers are the ones who owe most allegiance to the construction industry. It is high time that all civil engineers recognize their vital role in the construction industry and shoulder their fair share of the responsibilities for its success.

Responsibility of the Educators to the Construction Industry

The individuals among civil engineers who have been most laggardly in recognizing their responsibilities to the construction industry are the educators. There has actually been an aloof attitude on the part of civil engineering educators with their established, traditional type of curriculum. It has been based on developing in the students a scientific foundation of fundamentals to serve them in producing a technologically sound design for a works to be constructed. It has taught the civil engineering student how to produce a design but without adequate appreciation of the method and economy involved in its becoming a reality by construction. The educators must recognize the significant part that many of their students will play in the development of constructed works beyond design and shoulder sufficient responsibilities to account for this for the good of the industry they serve.

In the early developments of civil engineering curricula there was undoubtedly sound justification for terminating the undergraduate education with the design step based on theoretical considerations. The reasons for this need but little historical reflection. Projects such as the Erie Canal and the Boston Post Road and the bridges along or over them were for necessity of commerce or transportation and communication. They were the lifeline of the colonies and later this infant country. Even the more recent crossings like the George Washington Bridge or the Holland Tunnel were necessary to handle the multitude of traffic and transportation problems. Likewise, the original water supply facilities for the expanding cities of this country were

necessary to maintain safe and healthy conditions. The justification for the expense of these civil engineering works was based on the necessity for healthy citizenry and business for survival of the young nation. Furthermore, these projects could be financed by enterprising investors with a comparative wealth of capital for speculative investments.

Over the centuries or decades of time since those original civil engineering projects were conceived, designed, financed and built conditions for similar ones have changed appreciably. Even in the short interval of a quarter century the changes have been sufficient to necessitate an extreme change in civil engineering curricula. The majority of projects are no longer in the category of necessary originals but instead they are convenient improvements or modernizations. Necessity with extreme safety has given way to comfort and convenience with economy and impressiveness. Furthermore, the private investment capital that was in relative abundance at the time that paved highways, large bridges, skyscraper buildings, and mammoth factories were first built is no longer in the control of individuals. What is now available is in the coffers of larger corporations or holding companies where many people are watching each capital investment for its soundness rather than speculation. What is not under the control of large private organizations is, of course, available from tax funds to be spent under the watchful, collective eye of the multitude of taxpaying citizens.

Such changes, which have taken place in three short decades, have forced the practicing civil engineer to alter his approach and philosophy toward his work appreciably. Formerly, he designed a bridge or building for reasonable safety and service based on what he had learned about the theoretical aspects of design in concrete, timber or steel. The job of selling his design to the investor was left to a promoter. Nowadays the civil engineer must make sure that his product from the design board will pass the test of careful and extensive economic calculations. His design must not only be safe and functional but also be an improvement over existing facilities with optimum economy of materials, construction and operation as the final goal. To prove this economy in his design the civil engineer himself often has to try and sell his product to the multitude of individuals or citizens, who might buy it. With these obvious changes of professional endeavor before their eyes why have not the educators of men entering the civil engineering profession kept up more readily with the times? A modern civil engineering curriculum should adequately meet the challenge for a civil engineering graduate as a professional man serving the construction industry.

Scope of a Civil Engineering Curriculum to Benefit the Construction Industry

The basic sciences of the traditional civil engineering curriculum—mathematics, chemistry, and physics—are still indispensable to a modern curriculum. This is as true as the fact that the definition of engineering passed down through the ages is still applicable today. Engineering is still "The art and science by which the properties of matter and the sources of power in nature are made useful to men in structures, machines, and manufactured products." The properties of the materials and the sources of power in nature must be originally studied for their chemical and physical composition. The civil engineer should understand the fundamentals of chemical elements and compounds and the changes that can take place by

chemical reaction. Only with such knowledge can he hope to comprehend the manufacture, properties, and control of his infinitely useful materials such as concrete. How else can he hope to understand the production of the variety of steels or other metals he may use? The civil engineering student must still learn about the physics involved in the passage of light and images in the use of his indispensable surveying instruments. The physics of heat effect and transfer is still a fundamental problem in the allowance for expansion and contraction of his metals and the setting of his concrete. And the effects of gravitational pull and the Laws of Newton introduced in physics are as important to the civil engineer today as they were a century ago. The mathematics necessary for the solution of the reaction equations of chemistry and the equations of the physics laws is as important today as ever before. Furthermore, many many areas of knowledge and endeavor in the more specialized field of civil engineering necessitate a sound background of mathematics—for example, consider surveying, hydraulics or structural analysis, to mention only a few.

The person whose primary interest is in engineering applied to construction often does not think of the basic science studies as directly beneficial to his interest. If that is the case, he has taken a narrow, uncooperative and unimaginative viewpoint. He has foresaken the accepted, defined purpose of his profession to make the materials and power in nature useful to all mankind. He has taken principles and the laws of nature for granted. He has resorted to the convenience of handbooks, tables, rules of thumb, and letting the carpenter or mechanic do it as best he can based on his experience. He has fallen into the trap of shortsighted expediency for the sake of money and economy of time. Because of this lack of interest by the construction engineer in improving the standards and understanding of engineering sciences applied to construction, the majority engineering educators probably do not recognize the potential for advancing the education of engineers for the construction industry. They do not seem to recognize the need for field construction engineers having better engineering knowledge of such basic problems as pressure from wet concrete or stability of open cuts in earth. Though these problems cannot be licked solely by better understanding of the basic sciences, a sound background in chemistry, physics, and math is essential in the attack on them. The need for a modern civil engineering approach to go hand-in-hand with the ever changing know-how and ingenuity of the contractor is involved. The basic sciences can help this development tremendously.

Summary of Coursework for the Construction Engineer

This paper has been written to point out what one civil engineering educator believes should be included in a modernized undergraduate curriculum to particularly benefit the construction industry. The coverage is not intended to be all-inclusive. For instance, the desirable studies of engineering report writing or public speaking or highway engineering have not been mentioned. To summarize what has been discussed in this paper, the following outline of required studies is suggested for construction engineers.

Basic Sciences

Chemistry—to learn about the elements and compounds of the materials of construction.

Physics—to learn the fundamentals of optics involved in surveying, electricity involved in electrical power systems, and heat effects on materials and in machines.

Mathematics—to provide the tools for solving a great variety of engineering and other construction problems.

Engineering Sciences

Surveying—to be able to lay out construction in the field with due regard for accuracy, efficiency and economy.

Materials—to understand the production and properties of the engineering materials as they influence their use for construction.

Mechanics—to learn the fundamentals of statics and dynamics as tools for solving problems involving structures, construction equipment, and the like.

Design and Analysis

Structures—to be able to solve the variety of problems in construction, generally involving temporary structures.

Soil Mechanics—to learn how to cope with soils as they are found and handled in the field construction.

Electrical and Mechanic Power Units—to learn the fundamentals of power forms most frequently utilized in construction equipment and operations.

Economics and Management

Engineering Economy—to understand and appreciate the fundamental elements and factors that make up the cost of engineered construction work.

Labor Relations—to appreciate the problems of working with labor governed by contracts and laws to accomplish construction work.

Engineering Law—to learn the fundamentals of law that can be applied to understanding business operations and construction contracts and specifications.

Construction Methods—to understand and be able to plan for the construction forces that can be combined to accomplish acceptable and economical construction.

Business Methods—to learn how record-keeping and other business operations can be maintained for the complete success of construction work.

With study in these subject areas as a part of the civil engineering curriculum in colleges of engineering the construction industry should expect well prepared graduates in its employ whom they could call construction engineers. It should be recognized that this amounts to an ambitious extension of the traditional undergraduate civil engineering program. If the construction industry is interested in receiving this benefit it should be willing to help the colleges of engineering to the best of its ability. The needed help should be in the form of technical assistance and contributions, money to finance the program, and advisory guidance.

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ENGINEERING EDUCATION AND THE CONSTRUCTION INDUSTRY: MODERN TRENDS IN CONSTRUCTION ENGINEERING EDUCATION

Robert L. Schiffman,[1] J.M. ASCE

FOREWORD

Construction is this nation's largest single industry. Its 1957 dollar volume was 47 billions of dollars, or 11 per cent of the gross national product, yet it is a large anamorphic thing with no organization and no plan. At that, it offers civil engineering a new area of opportunity, according to Oglesby, ". . . to regain its position among the professional and scientific fields."

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ABSTRACT

This paper examines the current trends in engineering education towards a first degree in the engineering sciences, and professional training similar to Law and Medicine. In particular this paper looks at the needs of the construction industry in view of these trends in education. It is concluded that with the establishment of an organized job training program the construction industry can greatly benefit from such a program, in that future engineers will be well versed in the basic sciences, and will be able to bring these achievements to the industry, unhampered by preconceived notions of construction "hardware."

The title of this symposium in detailed aspects presents many of the problems of engineering education today. In one instance it can imply that the engineering colleges owe an educational debt to the construction industry, and therefore should follow the needs and requirements of this industry in curricula matters. Another, possibly independent implication of this statement, is in the form of a plea of the construction industry to the colleges to examine their needs. This plea can be in the form of a desire for a vocational type of education, or the recognition that the engineer on the construction job should

be college trained, and that the day of the illiterate in construction is happily gone forever.

Prior to any discussion of the needs of the construction industry, and the desirability of specialized education oriented to a given industry, it might be wise to examine the general modern trends in scientific education in general, and in engineering education in particular. There has been a trend toward humanization of the curricula. The emphasis upon the humanities has vastly altered the entire approach to engineering. It was only fifteen years ago that a leading eastern civil engineering school offered nine credit hours in liberal arts out of a total of one hundred forty nine credit hours required for a batchelors degree. These nine credit hours consisted of three courses, one being freshman English, the second being public speaking and the third being elementary economics. In the case of English and economics, there were special sections for engineers, since they were allegedly incapable of the same achievements as other students. Such a disregard for the liberal arts is unthinkable today, and the present feeling among many engineering educators is that the 20% to 30% of the curriculum presently devoted to the liberal arts is insufficient.

Another trend that has arisen, since World War II, is the gradual emphasis on science of "Why," and the deemphasis of old-fashioned engineering and the "how to" approach. Just about every engineering curriculum has in varying degrees shifted the emphasis to the sciences. The reasons for this shift are direct and simple. Our technological society is becoming so complex, that the solutions to engineering problems can no longer be attacked with procedural or rule-of-thumb methods. As a result, the engineer is relying in greater measure on the fundamental sciences to achieve solutions to everyday problems. In performing this shift there also has occured a polarization of the engineering curricula about the engineering sciences. Realizing that to compete in this modern world the engineer must be able to cross disciplines. Many academic institutions have abandoned the traditional degrees by branch and are awarding all engineering graduates a single batchelor's degree in engineering science. This movement to a more general and centralized degree is not a mere ripple of a radical fringe of schools, but on the contrary, is a ground swell of ever increasing proportions, in which year by year more and more of the larger engineering schools are converting their entire program to a common degree oriented to the basic engineering sciences.

This is the future! It now remains only to discuss whether this future bodes well, indifferently, or poorly for the construction industry. In considering this, we must accept as an absolute that in a modern engineering curriculum, courses formerly entitled "Construction Methods," "Construction Equipment," and the like, are not included. Thus, it would seem on first glance that the present trend in engineering education is to remove any emphasis towards training men for the construction industry. This is not necessarily so, and in fact, upon deep and subtle reflection, the removal of "hardware" courses from our curriculum will eventually be at great advantage to the construction industry.

At present, courses that are directly oriented to construction, are best taught by academic personnel, who have had a wealth of experience in industry. These people, bring to the student some portion of their own experience and ideas, in the hope that progress will be achieved. Since construction is not a theoretical science, all that the teaching can hope to do is to pass on

previous experience. Thus, the teaching of construction methods can be at best a long look into the past. Except from a historical point of view, this is completely contrary to the aims of education, one of which is a look into the future. A program in the engineering sciences, will develop in the student a higher degree of detailed knowledge of all the fundamental sciences, so that the young engineer interested in construction will be in a position not only to solve the old problems, but also to make advances in the art of construction, unhampered by preconceived notions and dogmas.

It may be argued by some, that the technical emphasis in an engineering science program is unbalanced for the needs of construction, and that it would be best that the preparation for a career in construction be less technical and be devoted more to the social sciences. This is, from an off-hand view, certainly true. Upon closer examination, however, it should be apparent that the construction industry by its very nature is probably more diverse than almost any other branch of Civil Engineering. Just considering the various trades employed on the usual construction job, the competent engineer must be well grounded in all subjects. From the start of the job, the engineer should be familiar with surveying, to layout the site. During excavation he should be qualified in soil mechanics, so as to supervise proper excavation procedures, such as the proper slopes, unwatering and other problems related to the foundation. With the building of the superstructure the engineers must be familiar with the principles of structural engineering, as well as hydraulics for piping, mechanical engineering, to supervise the mechanical trades, and electrical engineering to supervise the electrical trades. These are only the technical aspects of the construction engineer's work. In addition to these technical aspects, the construction engineer must be able to administer and must be capable of undertaking accounting procedures. No four or even five year engineering program will supply sufficiently all the factual knowledge necessary for absolute competence in all the above fields. The reasonable alternatives are two in number. In the first place, we can rely completely on an apprenticeship training, on the job, to develop competent construction engineers. In light of the present economic development of the United States, this throwback to the early days is costly and unwise, and will not fit the needs. The apprentice system may train, after many years, men capable of supervising one type of construction, but will not train engineers capable of competence in the many diverse forms of building. The second alternative is to employ engineers with a broad, well grounded knowledge in the fundamental sciences, and then to establish, through the professional societies, a relatively short (one to two years at maximum) program of job training to acquaint the budding construction engineer with the particular problems of his industry. Such a program of job training is not novel in industry. Some segments of the steel industry do just this in their "loop courses," and find it so successful that it is almost a requirement for any one hoping to rise to executive status. Such programs are beneficial to every one concerned. To the engineering colleges, these programs enable the concentration on fundamentals, and the elimination of courses devoted to "hardware." To industry they are beneficial, in that the particular needs of industry can be satisfied by those people who are the best judges of those needs, namely the members of the industry in question. This program has the further advantage that it fits the current trends of engineering education, toward the engineering sciences.

Today's engineer to be qualified in a specific branch is generally required to pursue an advanced degree. As our technology expands, the undergraduate program will be increasingly devoted to the fundamental sciences, and the engineering specialization will be reserved for a graduate program of professsional training similar to Law and Medicine. The eventual universal adoption of such a curricula is not in doubt. The only question is whether the various industries, such as construction, will make the best use of this program.

In order best to utilize manpower emanating from the colleges of the future, it is suggested that the construction industry consider adopting a type of "loop" course program to train the graduating engineering scientist in the specialties of the industry. This program should not be left to individual contractors to administer, due to financial considerations, and to the considerations of giving the young engineer the broadest possible background. It is suggested that this program be administered by the professional societies, and that they, through their committees, plan the program, and administer placement of personnel in the program, with the consent and advice of the individual contractors involved.

To return specifically to the needs of the construction industry vis-a-via the engineering colleges, they are mainly the training of young men in the fundamental sciences, so that upon graduation they will have achieved the proper background for specialized study and work in construction. In this way, we will not only raise professional standards from the "hardware" school of endeavor, but will open construction to the modern sciences.

Journal of the
CONSTRUCTION DIVISION
Proceedings of the American Society of Civil Engineers

ENGINEERING EDUCATION AND THE CONSTRUCTION INDUSTRY: THE ENGINEERING PROFESSION IN CONSTRUCTION

Roger Corbetta[1]

Construction is this nation's largest single industry. Its 1957 dollar volume was 47 billions of dollars, or 11 per cent of the gross national product, yet it is a large anamorphic thing with no organization and no plan. At that, it offers civil engineering a new area of opportunity, according to Oglesby, ". . . to regain its position among the professional and scientific fields."

At the roots of this point is the everlasting dichotomy between the construction industry and the institutions of higher learning which turn out civil engineers. This must be resolved before we can enter upon an era of true progress. The old days when "college-kids" had to stand in awe of the time-worn construction superintendents who came up through the school-of hard-knocks are fortunately coming to an end. Numbered also are the days of wastefulness caused by hyper designs from those devoid of any idea of what problems a field man faces, trying to construct those didactic details.

Our contemporary construction methods, materials, and machines can only be handled by technically trained individuals. Modular building parts; pre-stressed concrete; precast, tilt-up units; thin shells; soil mechanics; heavy nuclear sections; super highways; jet-age airports; launching pads; light aggregate; new cement formulae; lightweight alloy structural members; stabilized soils; complex multi-purpose and/or specialized machines are all the end result of scientific thinking and require engineers to use these tools to translate paper designs into tangible structures. This is construction!

We realize the divergent thinking that shapes the attitudes of the workers and the teachers will not be united in a thrice, but this committee feels that the opening of this whole topic for discussion will hasten the day. Six papers were solicited from what we felt were the six most stimulating sources, three from each camp:

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1. Pres., Corbetta Construction Co., New York, N. Y.

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M. D. Morris, M. ASCE
Chairman, Construction Division
Committee on Publications

ABSTRACT

The European method of one man being responsible for a turn key job from start to finish should be applicable here, that is, the conceiver and designer should also be the estimater, construction consultant and constructor, so that any person is responsible himself for a job from start to finish. This is the essence of my opinion of good construction practice and education for this should be in terms of the means toward the end.

What the Construction Industry should have from Engineering Colleges is a constant flow of new CONSTRUCTORS qualified to design and build their own structures.

Equally important is the need for Engineers with an instinct for evaluation of quantities and design.

The proper appraisal of quantities, conditions, and development of schematics in construction is the key to successful construction firms.

Scheduling of work units, organizing workers, and instructing men in sequence of operations to be performed with speed, safety and economy in orderly fashion is a task for which Engineers should be trained.

LEADERSHIP is as important in the Construction Industry as in any other field. Perhaps a concentrated course in PUBLIC SPEAKING would create SELF CONFIDENCE in the student, and thereby develop him in the art of

influencing people by his ability to express himself in a group. One's point of view is more readily accepted if presented clearly and without timidity and, therefore, encourages that person to carry on more effectively. A timid person, although brilliant, is sometimes frustrated because of his inability successfully to convey his ideas to others.

The Construction Industry and the Engineering Profession, as well as the Public at large, would ultimately benefit by encouraging ENGINEERING students to think in terms of establishing their OWN building and/or construction firms. Emphasis should be placed on the advantages of selling their services on the basis of furnishing Design AND Construction as a "single package."

The present custom of Architects, Engineers and Contractors being separate entities, too often completely disinterested in each other, is most inefficient and costly. The European custom of the Architect and/or Engineer being required to construct his own creation should be given serious consideration for the future.

The concept of the Architect and/or Engineer being Contractor as well as Designer would make for appreciable economy through the elimination of present-day methods of inspection on the part of Owners and the Designers.

The benefits that will accrue from the curtailment of excessive indulgence in so-called "factors of safety" due to the uncertainty on the part of the designer as to, "Who will build this structure?", are inestimable.

Public Building Departments could be curtailed materially - perhaps eliminated - if licensed, Professional Engineers would not only design but build their own structures and, consequently, assume full responsibility of the structure as to safety.

Certainly, a licensed, professional person should be relied upon to conduct the construction operation with the proper element of safety and honesty, especially if failure so to do would mean loss of license and perhaps other appropriate punishment.

Engineers should be trained to assume full responsibility for their design. In no better way can they accept more completely this full responsibility than to construct the structure and not limit their activities to the design alone.

CIVIL ENGINEERING should not be fearful of great numbers of young folk today leaning toward the subject of outer space and other kindred subjects, because Civil Engineering can manage with a fewer number but better qualified students and graduates.

Those not blessed with aptitude, understanding and resourcefulness, courage and daring, would be more happy in life if advised and encouraged to engage in some other occupation more suitable to their ability and liking. They should be discouraged from pursuing the subject of Engineering.

Serious consideration might be given to the many advantages that would accrue to the Engineering Profession, the Colleges, and the Construction Industry if one of the requirements for entering a College of Engineering be that applicants must have had a minimum of two years experience on construction work in the field, and credits be given on the basis of the varied types of work performed in that period. Two years field experience might well help a Student to decide the extent of his interest in Civil Engineering and Construction. The Student with field experience would be better qualified to grasp the problems and study of Civil Engineering.

What the Construction Industry NEEDS is:

1. A constant flow of new CONSTRUCTORS qualified to design and build their own structures.

2. Engineering Colleges should concentrate on development of INGENUITY in Construction and encourage a keen interest therein.

3. Perhaps periodic talks on "Experiences in Construction" by successful Contractors might be helpful in inspiring and whetting of appetities of Students for Construction from design to turnkey.

4. Outstanding men are those who have an affinity and passion for their professions. It is useless for one not possessing a natural good voice to aspire to prominence as a singer.

Journal of the
CONSTRUCTION DIVISION
Proceedings of the American Society of Civil Engineers

ENGINEERING EDUCATION AND THE CONSTRUCTION INDUSTRY: CAMPUS TO CONSTRUCTION

H. A. Letoile [1]

FOREWORD

Construction is this nation's largest single industry. Its 1957 dollar volume was 47 billions of dollars, or 11 per cent of the gross national product, yet it is a large anamorphic thing with no organization and no plan. At that, it offers civil engineering a new area of opportunity, according to Oglesby, ". . . to regain its position among the professional and scientific fields."

At the roots of this point is the everlasting dichotomy between the construction industry and the institutions of higher learning which turn out civil engineers. This must be resolved before we can enter upon an era of true progress. The old days when "college-kids" had to stand in awe of the time-worn construction superintendents who came up through the school-of-hard-knocks are fortunately coming to an end. Numbered also are the days of wastefulness caused by hyper designs from those devoid of any idea of what problems a field man faces, trying to construct those dedactic details.

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1. Perini Corp., Framingham, Mass.

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ABSTRACT

Most times the construction industry does not get what it wants from the colleges and henceforth is obliged to do something in order to fill the gap of what they get from the colleges and what they desire for their practice. This one organization has established its own four year training program, to take a college graduate, put him through this and evolve with a young construction executive. This is one method of arriving at properly trained personnel for this field.

In dollar volume, number of employees and almost any other yardstick, the construction industry is the largest in the world. Strangely, however, very few of our universities and technical schools offer courses specifically designed to prepare young men for careers in construction. In fact, the recent educational trend has been to stress theory more and more, and to leave the practical approach and application of theory to the employer. With this emphasis on theory, the development of the "specialist" came into being, and while there may be a place for him in other fields of science, generally speaking, the opportunities for such a man as a construction supervisor are limited.

This is not meant to imply that a first-rate contractor does not employ specialists. There are men who perform certain specialized tasks — such as pre-stressed concrete, for instance — and eventually become supervisory heads of such departments within large construction organizations.

However, most of our heavy construction companies perform all types of work -- dams, bridges, highways, tunnels, powerhouses, railroads, etc. — and it is probable that any one company will have a preponderance of one or two of these types of projects over a given period. Therefore, a man whose training has been guided through a variety of projects, and who can adapt himself to supervising any type of job, is an invaluable asset to a heavy construction contractor. The top-salaried supervisors in heavy construction today are men whose experience is so varied that it affords their employers flexibility of assignment no matter what type of project comes along.

Various contractor associations have approached engineering schools in an effort to supplement the teaching of theory with practical courses in construction, but most educators seem opposed to such programs. Consequently, the contractors have found it necessary to assume the task of practical job training from campus to superintendent.

What further development and training is required by the construction industry for engineering and technical graduates? Like most industries, construction candidates are required to go through a period of training designed to apply their theory and book learning to practical construction problems, and to deal with and handle men in the performance of construction work.

Until recent years, most training programs in the construction industry were informal and not too clearly defined as to time or objective. Unlike most industries with formal training programs — industries with manufacturing processes, plant locations, products, and the like that enjoy a certain amount of stability — the contractor performs his work in a variety of locations and invariably the projects he builds are well diversified. In Fig. 1, the Priest Rapids Dam job is a good example. Consequently, supervisory training in the construction industry must, of necessity, be flexible, but it is noteworthy that in recent years some industry leaders have formalized their construction training and the results have been very rewarding.

Six years ago, for example, one of our leading contractors embarked on a four year formal training program for engineering graduates designed primarily to develop supervisory personnel. Although the four year period is basic, the program itself is flexible so that the trainee can be given longer training on his weaknesses and devote less time on his strong points. However, the company does not allow the trainee to omit any of the program's required phases.

Word of success gets around fast in the construction industry, particularly when two or three young engineers under thirty years of age blossom out as full-fledged project managers on multi-million dollar projects. As a result, other progressive contractors followed suit and instituted with almost identical trainee programs.

Basically, a construction training program includes the following phases, although the time element for each may vary with the company:

1. Quantity Take-off and Office Procedures	4 Months
2. Mechanical	4 Months
3. Electrical	4 Months

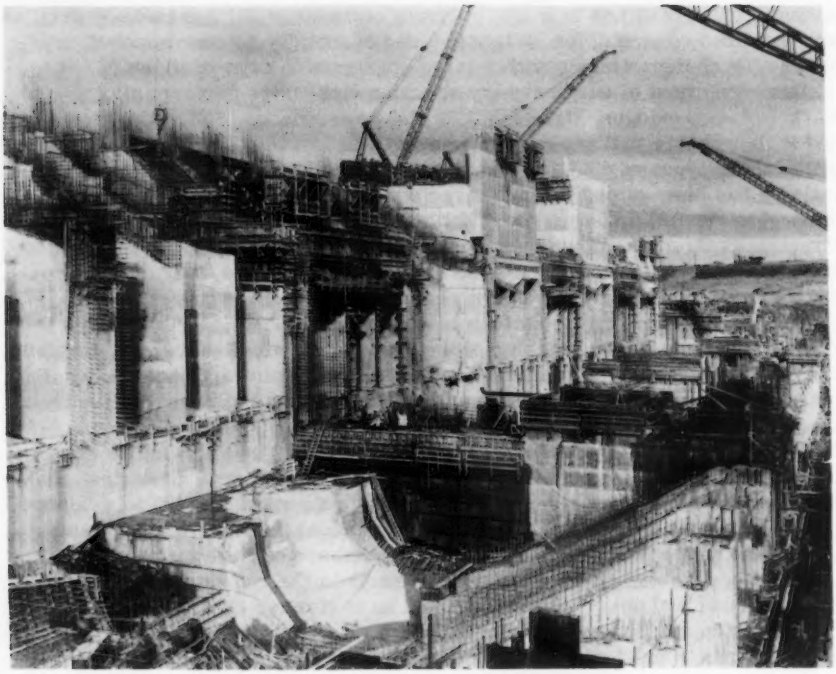

Fig. 1. – Priest Rapids Dam.

4.	Field Engineering and Layout	4 Months
5.	Carpenter Foreman	9 Months
6.	Concrete Foreman	3 Months
7.	Excavation and Grade Foreman	3 Months
8.	Rock Drilling and Grouting Foreman	3 Months
9.	Drainage and Structures Foreman	3 Months
10.	Cost Engineering, Purchasing, Administration	5 Months
11.	Estimating	6 Months

A trainee gets a major dose of cost problems in the mechanical and electrical phase. The company does not intend to make a mechanical expert out of him in four months, but he is expected to acquire the knowledge any good superintendent should have by working with a master mechanic. In this course the trainee analyzes the equipment repair costs, the time involved in making repairs and the production loss resulting from out-of-service equipment.

The trainee gets his first taste of supervision when he is sent out as a carpenter foreman. He is given a crew of men for which he is responsible. He does form work and keeps track of costs, materials and labor. This

training phase, as well as all other foreman phases, may be split into two separate jobs such as power house or a highway bridge.

As a concrete foreman, a student is given a crew of men and is in charge of concrete placement. If the trainee has worked on a highway or a dam during his first foreman job, the company will attempt to put him into tunnel work during his service as a concrete foreman.

When he has completed the various foreman courses, the trainee returns to a company office for cost engineering, purchasing, administration and estimating. This last phase -- estimating -- is a separate course, and with the combination of experience in the field and in the office the student is in a position to take off quantities and start pricing the items for which the company is submitting bids.

With the completion of the estimating course, the trainee has finished four years of the program. Not all trainees, of course, can make the grade in four years, so now the company must appraise the trainee and determine his capability before allowing him to assume supervisory responsibility. Generally, companies have found that trainees who worked on construction during vacations while in college are most likely to succeed in four years.

Upon completion of the course, the trainee is assigned as an assistant superintendent or assistant engineer. For six months he is sent out to one project and given the responsibility of several work crews, reporting either on the project manager or the general superintendent. The next six months -- still serving as an assistant superintendent or assistant engineer -- the trainee works on a different project under another project manager.

When the final year of training is completed, a successful trainee is graduated to the position of superintendent in charge of a construction job. From here on the man's progress is up to himself. His work is guided by higher officials of the company and promotions to project engineer, project manager, and finally company executive will usually follow as fast as the man develops. A good construction firm can only grow successfully in proportion to the number of well-trained men it develops.

To sum up, a construction training program is no bed of roses and demands hard work, long hours, patience and initiative. Yet today success in business can only be achieved by this type of serious application by the individual. The rewards, however, are great -- not only from a financial standpoint, but also from the satisfaction that comes from accomplishment and the knowledge of the invaluable contribution the men of construction make daily to the well-being and economy of the United States and our way of life.

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Journal of the
CONSTRUCTION DIVISION
Proceedings of the American Society of Civil Engineers

ENGINEERING EDUCATION AND THE CONSTRUCTION INDUSTRY: WHAT THE INDUSTRY SHOULD HAVE FROM THE COLLEGES

C. H. Oglesby,[1] M. ASCE
and John W. Fondahl,[2] A.M. ASCE

FOREWORD

Construction is this nation's largest single industry. Its 1957 dollar volume was 47 billions of dollars, or 11 per cent of the gross national product, yet it is a large anamorphic thing with no organization and no plan. At that, it offers civil engineering a new area of opportunity, according to Oglesby, ". . . to regain its position among the professional and scientific fields."

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1. Prof. of Civ. Eng., Stanford Univ., Stanford, Calif.
2. Asst. Prof. of Civ. Eng., Stanford Univ., Stanford, Calif.

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ABSTRACT

This paper attempts to face up squarely to the joint problems confronting civil engineering education and the construction industry. Construction should not be considered as a business but as a definite corner of the civil engineering profession. A civil engineer must therefore make the most use of his knowledge acquired in college in order to do the work of engineering and management. The civil engineering profession has much to gain by strengthening its ties with construction and it should be done by construction sponsored research in the colleges, as well as bolstering of the college curriculum.

INTRODUCTION

The "Report of Task Committee on Professional Education"(1) prepared by a group of distinguished members of the American Society of Civil Engineers merits the serious attention of all Society members. Its findings leave little

room for complacency; rather they demonstrate clearly that civil engineering has lost stature when compared to other fields of engineering and science. Among the reasons given for this loss are that other fields appear to offer greater challenge and opportunity, a higher regard from the public, and larger financial rewards.

The Task Committee made several recommendations for improving the status of civil engineering. One of these was that "The American Society of Civil Engineers should give greater attention to the needs of the construction industry and to the development of programs whereby the Society and the engineering colleges may better serve the industry." Without question, this recommendation offers real possibilities. Construction, basically is a civil engineering function. It requires the knowledge and application of such fundamental subjects as structural theory, soil mechanics, hydraulics, and engineering economy. It is true that construction combines management functions with civil engineering, but so has manufacturing combined mechanical engineering with management. Construction is the nation's largest single industry, with a 1957 dollar volume of $47,000,000,000, or 11 percent of the gross national product. It offers an almost new area of opportunity that can help civil engineering to regain its position among the professional and scientific fields.

In the past, the prevailing attitude of civil engineers and civil engineering educators has been that construction is not a part of civil engineering. As a result of this attitude, construction has been largely ignored in civil engineering education. However, since World War II, a growing awareness of and attention to construction has been developing in a number of engineering schools. It is the purpose of this paper to explore briefly the following topics regarding education for construction.

The place of the civil engineer in construction.
The responsibility of civil engineering schools to educate men for the construction industry.
The contribution that civil engineering schools can make to construction.
Current practices and trends in engineering education for the construction industry.

The place of the civil engineer in construction

As indicated above, the Task Committee on Professional Education recommended that the Society and colleges should better serve the construction industry. This statement by the committee recognizes the Society's policy of including qualified men from the construction industry in its membership, thereby classifying them as professional civil engineers. As a matter of fact, members with construction interests constitute the second-largest segment in the society, if registration in technical divisions can be employed as a measure.(2) Of the 49,539 registrations for 1957 in the 14 technical divisions, 8,190 were in the construction division. Only structural, with 12,000 members, was larger. The next two most numerous listings were soil mechanics and foundations with 5493 and highway with 5280.

From a somewhat different point of view, that of the major industries with which civil engineers are concerned, construction predominates. A comprehensive survey made in 1946(3) shows that 65 percent of all the civil engineers polled are affiliated with construction activities, as contrasted with utilities 9.1 percent, personal services (including education) 7.4 percent,

manufacturing 7.4 percent, and transportation 4.2 percent. There is, then, much evidence that construction is an area of primary importance to civil engineers. On the other hand, many civil engineers do not consider construction a legitimate part of civil engineering. For example, the Task Committee reported that "only a small percentage of the educators interviewed believe that it is the responsibility of the engineering colleges to provide training in the practical and business side of engineering." Admittedly, "practical and business" and "construction" are not synonymous terms. Yet the parallel is close enough, when verified by several year's observation, to support the contention that many civil engineering educators believe that education for the construction industry is not a proper function of engineering colleges. Again, in some states the boards of professional registration discount or refuse to give credit for experience that has been gained in a contractor's organization. In at least one state organizations of consulting engineers have taken militant action to make professional registration for engineers in the employ of contractors difficult if not impossible. The model registration law sponsored by the National Society of Professional Engineers goes even farther. It singles out contractor's employees, and only them, for unfavorable mention. Section 12-6, titled, Work as Contractor, reads as follows: "The mere execution, as a contractor, of work designed by a professional engineer or the supervision of the construction of such work as a foreman or superintendent shall not be deemed to be the practice of engineering." While there is little doubt that in many cases the execution of such work is not equivalent to the practice of engineering, in other cases the "mere execution" of the work may require engineering skill and knowledge surpassing that of the professional engineer who is responsible for the design. Such a clause will probably result in construction experience being automatically rejected. There is no reason why both construction and design experience cannot be examined at face value to judge if an appropriate degree of engineering competence has been required.

This reluctance on the part of many civil engineers to admit that construction is civil engineering arises mainly through a failure to recognize how greatly construction organizations have changed in the last decade or so. In years past construction operations predominately were managed by ambitious tradesmen who by hard work and perserverance became owners and superintendents. Certainly these men, able as they were, could not be classed as civil engineers. In recent years this situation has changed markedly and the change is continuing at an even faster rate. As the president of one large construction firm puts it "Construction is being taken over by professional people - engineers, accountants and lawyers." Increasingly, graduate engineers are being employed by contractors to be developed into managers and construction superintendents.

There is much evidence to demonstrate how construction personnel is changing. Replies to a questionnaire circulated in 1955 by the Associated General Contractors,(4) if expanded to cover the industry, would indicate that the contractor's needs for civil engineers would equal the output of all accredited schools in the United States. Although these conclusions may represent an unwarranted extension of limited data, since it is based on a 12 percent reply to the questionnaire, they indicate clearly that contractors are turning increasingly to the engineering schools for their future executives and supervisors. Engineering teachers can testify that their graduates in large numbers are entering construction firms. Statistics gathered by the

Associated General Contractors[5] in 1955 indicate that between 15 and 25 percent of the civil engineering graduates enter construction on graduation and more change to it sometime after graduation. As a specific example, on the order of one-third of all civil engineering graduates from Stanford since World War II are with contractors. All the signs are that within a few years, a high percentage of all construction management will be graduate engineers.

At least two forces have contributed to the shift to engineers in management personnel for contractors. One of these is the increasing size and complexity of construction projects which demands that construction supervision have greater ability to visualize, analyze, and fit the many fragments into an integrated whole. Along with this increased complexity of work has come the realization by contractors that engineers are more than "trouble-makers" and "surveyors." Particularly during World War II, many contractors were forced to hire engineers or to work closely with them, and in so doing, the contractors discovered that engineers had talents that before had gone unnoticed.

A second reason for the shift to engineers is that trade unionism has clogged the traditional source of construction supervision, which was the ranks of skilled tradesmen. Contractors increasingly are saying that many of today's workmen have developed such strong union loyalties and are so ingrained with union thinking that they do not make good members of the management team. Also, tightened jurisdictional lines prevent the tradesman from gaining the breadth of knowledge so important in good supervision.

Civil engineers employed by contractors are often called on to do engineering design as well as management and supervision. In many cases the problems encountered are equal in difficulty, if not more difficult than those of the design engineers who developed the original plans for the project. For example, cofferdams, caissons, falsework and other temporary installations may present much more difficult situations than are involved in the permanent structure. Again, the design of contractor's plant often calls for skills from every area of the civil engineer's education, including structures, hydraulics, soil mechanics, highways, electrical engineering, and thermodynamics.

The picture of construction work on the Baltimore harbor tunnel (Fig. 1) shows some of these skills in operation.

Why do large numbers of civil engineers find work with contractors preferable to that in the more traditional areas? No single answer applies in all cases, but some of the most common are:

1. Construction offers earlier opportunity for responsibility. In most contracting organizations, engineers quickly are placed in positions of responsibility where they are faced with technical and management decisions of considerable importance. In contrast, in many public agencies and private design offices, young engineers may serve several years in routine surveying, drafting, and other menial chores before they have this opportunity. Word of these differences travels fast on the college and post-college grapevines and soon influence both new employment and job transfers.

Many civil engineers feel strongly that college graduates need several years apprenticeship before they are given authority to make important decisions. This question could be argued at length, but is not pertinent to this discussion. If the young engineer has a choice, he most certainly will choose the position that promises early responsibility.

Fig. 1. — Baltimore Harbor Tunnel.

2. Construction offers a feeling of permanence and belonging. The construction industry is becoming increasingly aware that the key to success is talented and loyal personnel. Where once contractors hired men for a single project and dropped them when it was over, many firms now offer permanence better than that in numerous engineering offices. At the same time, the contractors often have profit-sharing and bonus plans and retirement and insurance schemes equal to or better than those available elsewhere, and even more important, contractors are including their engineers as members of the top management team to a far greater extent than many engineering firms do.

Contrary to popular belief, the writers' experience indicate that permanence in employment, once the trial period is over, is as good with contractors as with public agencies and most private engineering firms. In contrast, continuity of employment is least certain with the private consulting firms that have highly variable work loads. The design staffs of some engineer-contractor firms are likewise affected. Engineers with these firms often find themselves included in a pool of engineers and draftsmen that moves from company to company. Many of them have the status of temporary employees and have little chance to ever become truly a part of the firm.

3. Construction offers financial incentives to the man who is willing to work for them. As a general rule, starting salaries with contractors are about the same as with public agencies and private consulting firms. However, the engineer who does well with a contractor will find that salary

increases come more rapidly and that the ceiling is higher than in other fields. In common with private practice, construction also offers the opportunity for the man to have his own business. This avenue is of course closed to the engineer who chooses public works as a career. On the other hand, construction is not for the man who wants a 40-hour week with the leisure time activities that accompany it. He must expect long hours and an intensive work pace.

4. Construction offers a wide variety of problems requiring the use of every phase of the engineer's education. Moreover it is probable that each day will present new situations. Many engineers feel that such diversification offers more challenge and stimulation than those fields that tend to invoke specialized or routine duties.

Thus, construction offers challenge, financial rewards, and variety of work equal to or better than that found in other areas of civil engineering.

The responsibility of civil engineering schools to educate men for the construction industry

Central to the problem of civil engineers in construction is the recommendation of the Task Committee that the engineering colleges better serve the construction industry. This recommendation implies that engineering schools have a responsibility to alter or supplement their present offerings in order to direct more attention to construction. The question is "Does such a responsibility exist?"

Spokesmen for the construction industry say emphatically that traditional civil engineering education should be modified to meet construction needs. Eighty-eight percent of the contractors who replied to the 1955 AGC survey stated that they preferred emphasis on training in general management, construction planning, and plant layout rather than in advanced engineering design. Any sampling of the opinions of engineering graduates now engaged in construction will provide strong support for this statement. Thus, if civil engineering schools wish to meet the needs of that segment of their graduates that enter construction a re-examination of present offerings is certainly in order.

The arguments of those from the industry will carry little weight with engineers and engineering teachers who believe that construction is really not civil engineering and that those who enter it are in reality leaving the profession. However there are other considerations. For one thing, civil engineering designs are not an end in themselves; they must be converted into concrete, steel, and other materials, and this conversion is called construction. If the designer knows nothing of construction practices, procedures, and costs he cannot possibly produce really economical designs. Neither will be be able to oversee construction work properly and fairly. Thus, some minimum knowledge of construction is essential to civil engineers as designers and field engineers.

In a broader sense, civil engineering as a profession will gain far more than it loses by strengthening its ties with construction. First of all, the glamour and appeal of construction will attract many able young men into civil engineering schools as an avenue into construction. Enrollments will increase in contrast to the present decrease, which will help to regain some of the status that has been lost to other branches. Other areas of civil

engineering will also gain men, as some of those who start toward construction will develop other interests instead. In years ahead the American Society of Civil Engineers and other professional societies will be strengthened by an increase in membership. Construction practices will themselves be improved for, with more civil engineers in construction, there will be increased probability that the ideas and wishes of the design engineer will be followed closely, since the contractors' staff will better understand the designer's intentions. Construction work will proceed more smoothly and harmoniously, because of mutual understanding between designer and field engineer on the one hand and contractor on the other. The end result will be better and more economical projects for the engineer's clients.

It is also worth while to consider the results if civil engineering education largely ignores construction. In the first place, construction is demanding and will find technically trained personnel since it offers the rewards that attracts competent men. Thus, if civil engineering does not meet its requirements other branches of learning will. Already some schools of architectural engineering, architecture, and business have developed curriculums specifically aimed at construction. As of 1956, at least nineteen schools offered curriculums and degrees in "light construction"(6) and numerous others have discussed programs in construction engineering. Industrial engineering and management consultants also are looking toward construction as a fruitful field. The signs are plain: if civil engineering ignores construction, other schools and departments will absorb it or new departments will develop. There is, for example, the case where mechanical engineering grew away from manufacturing and left a void that is now filled by industrial engineering.

The Contribution that Civil Engineering Schools Can Make to Construction

Assuming agreement on the idea that construction is an integral part of civil engineering and that the schools have a responsibility toward it, there then is the further question "What contribution, if any, can the engineering schools make to construction?"

Before discussing this topic in detail, some consideration of basic ideas and attitudes is in order. First of all many engineering educators who are unacquainted with the subject think that construction courses are "trade school stuff" and not proper subjects for university study or credit. It must be admitted that construction courses can be taught at a trade-school level with principal attention devoted to routine computations, memorization, and endless details on "how to do it." However, this problem is not unique to construction courses; Are not many courses in structures, hydraulics, and highways taught by "handbook" methods, with little attempt to challenge the students' creative and imaginative abilities? In construction courses, as in other areas, the subject matter can be presented in a way that develops technical competence and straight thinking of a high order. As one of many examples, carefully designed problems in earthmoving can offer a serious challenge to the students' knowledge of statics and dynamics. Since construction procedures are less bound by restrictions, such as building codes for structures, they offer an excellent vehicle for developing curiosity and a critical attitude about present techniques and methods. In addition, construction courses provide a highly favorable atmosphere in which to treat subjects of

importance to civil engineers as professional men and citizens. These would include among others, engineering economy, construction costs, labor problems, accident prevention, and the legal aspects of engineering. The point of this argument is that construction as a subject should not be condemned or ruled out as being unsuitable for undergraduate or graduate college work. Condemnation, if any, should be aimed at the method in which the subject is treated.

Another impression of many civil engineering instructors is that there is something second-rate and even unethical about contracting. From such a viewpoint it is logical to reason that construction is not a worthwhile topic for professional engineers. This impression arose many years ago when "gyppo" contractors were numerous and dealing with them sometimes involved risking life and limb. To illustrate, the specifications for the Hetch Hetchy Dam of the City of San Francisco, dated May, 1919, contained a clause reading "— the intimidation of any engineer or inspector by the Contractor or any of his employees shall be sufficient reason to annul the contract." Old ideas die slowly, and many civil engineers still retain this impression. Worse yet, many engineering teachers continue to present construction in this light. These men fail to recognize that today construction is not only the country's largest industry but that it has "come of age." Too few engineers are aware that the day of the "gyppo" is largely passed, and that the construction industry is mainly under the management of highly qualified professional and business people.

Central to the topic of the contribution that engineering schools can make to construction is that of subject matter. This topic can best be approached in two parts. First, based on the assumption that construction is an integral part of civil engineering activity and that practically all civil engineers will have some dealings with the construction side of their profession, what subject matter should be taught to all students as a part of their required studies? Second, based on the belief that the construction industry is properly looking to the civil engineering schools for their future key personnel and that construction is a field worthy of attention at the college level, what specialized subject matter should be offered to students who wish to prepare for careers in the construction industry?

Considering the first question, it must be recognized that the four-year engineering curriculum is already crowded. At the slightest indication that the time given to any presently included subject matter might be reduced or released, there is strong competition from each field of specialization for that time. It follows that there can be little specialization and no room for the learning of mere techniques which can be acquired in later practice.

The authors feel that there are several bases on which courses can be justified as part of required undergraduate studies. These include:

1) That the subject matter have future value to the majority of students in their professional careers.

2) That the subject matter present fundamentals with which further knowledge can be acquired through graduate study or practice or both.

3) That the subject matter be such that either it is difficult to master through independent effort or that it is extremely unlikely that the majority of students will take the time to pursue it if left to their own choices.

4) That the subject matter develop the broad viewpoint rather than the restricted view of any specialized group in the profession.

The authors feel that a certain minimum knowledge of construction practices meets all of these criteria for inclusion in the four-year civil engineering curriculum. This does not mean that it is necessary or desirable to give construction topics a large segment of the very limited time that is available. However a person must have a starting point before he can, on his own, expand his knowledge of any complex subject. For example, much can be learned about the legal problems of contractor-engineer relations through the technical and daily press, but only if the man has some grounding in contract law and procedures. Otherwise the articles that he reads will be largely meaningless. Thus, two main aims of undergraduate construction courses should be to lay the groundwork for self-education and to stimulate interest.

What should every graduating civil engineer know about construction? He should have an idea of the problems, methods of doing business, and viewpoints of the contractor. He should be well-grounded in the obligations that he will have in the matter of contract administration. He should know that, as a professional engineer, he must act as an impartial judge in disputes between contractor and owner. He must realize his obligation to prepare specifications and contract provisions fairly rather than aimed in the single direction of protecting the owner and engineer — come-what-may. He must recognize that the plans and specifications that he prepares and his actions in overseeing the contractor must lead to safe and acceptable working conditions for those employed on the project. He must think straight about costs since he is not a good engineer if his designs are uneconomical. This involves more than merely designing for minimum material requirements. It demands a genuine appreciation of the advantages of repetition and mass production, re-use of forms, employment of standard rather than special items, and simplicity in details. It includes a knowledge of the elements that make up the cost of labor, equipment, and overhead. This in turn involves an introduction to such matters as typical union working rules, questions of labor jurisdiction, how to arrive at a realistic figure for owning and operating a piece of equipment under given conditions, and why "bid-unbalancing" may be a sound and justifiable practice under certain circumstances and a risky and unethical practice under others. Finally, he should understand the process of making an estimate and the procedure by which an intelligent contractor puts together a competitive bid. This will not only furnish him means for analyzing his own design work, but it will give him considerably more understanding in the administration of contract work as the representative of an owner.

Much of the material suggested above can be presented in the framework of courses now offered in the usual curriculum, for example, contracts and specifications and structural design. Ideally, all of this subject matter should be presented in such courses without artificial separation between design and construction. A major obstacle to such a procedure is that very few college professors have construction experience or even an understanding attitude towards the contractor's problems. If a faculty includes one or two men with such experience or understanding, then those men should offer the course in contracts and specifications, and consideration should be given to a course with some such title as "Construction Costs and Methods" to cover other topics mentioned above.

Considering the second question, if an engineers' education is aimed specifically at construction, he must have considerably more knowledge than that suggested above as a minimum for all civil engineers. He must learn something of the problems of law, finance, and labor relations which face all management. He should learn of the techniques and procedures from other disciplines, among them industrial engineering, that offer means of improving construction techniques. He should increase his technical competence so that he can design machines, structures, and devices that will economically and safely do their appointed tasks. All in all, the civil engineer in construction needs advanced professional training just as much as does the structural, hydraulic, or highway engineer.

Some attention to professional subjects needed by engineers in construction may be possible at the undergraduate level. However, it can be found only at the schools where the curriculum includes elective units and where construction courses are offered. Even at these schools, however, there will be room for, at the most, three or four construction-related courses. It follows that intensive study, if done in college, must necessarily come in the fifth year.

The report of the Education Committee of the Associated General Contractors of America, as reported in October 1956,(7) indicates the thinking of many contractors. It states, in part "The group endorsed in principle, as a long-range objective, the proposal by W. A. Klinger for the establishment of five-year college curriculum to educate engineers for the construction industry. (Mr. Klinger outlined his plan in January 1956 issue of THE CONSTRUCTOR.) The committee also recognized the immediate need of the bachelor of science degree in civil engineering which sould be awarded at the end of four years. The chief purpose of the five-year course, resulting in a master's degree in construction engineering, would be to train the student as a construction administrator."

It is pertinent at this point to raise the question, "Should the construction industry rather than the colleges provide advanced training for its engineers and future executives?" There are now a number of companies, such as the Perini Corporation,(8) who are doing so. In general, the plans place the young engineer in jobs covering the major phases of the companies' operations. Over a period of several years he works in the office on such assignments as quantity takeoff and estimating and in the field as a surveyor, cost engineer, and assistant to a superintendent. These training programs vary widely among companies. In some cases, the schedule of assignments is quite rigidly followed; in others the company's immediate needs take precedence over the training program. Some companies provide special lectures by company officials and employ other means to make the program meaningful; other companies place all responsibility for training on the supervisor under whom the trainee is working.

There are several reasons why the in-service training program is not a satisfactory solution to the over-all problem of education for construction. Among these reasons are the following:

1. In-service training programs are suitable only for large firms, since smaller companies do not have the work volume necessary to sustain a group of trainees. It follows that, since the great majority of contracting firms are relatively small in size, in-service programs will not solve the problem for most of the industry. To illustrate, the highway field is one in which the

work volume of firms is considerably larger than in many other areas of construction. Yet, of the members of the Highway Division of the Associated General Contractors, 92 percent are classed as small businesses since they do less than $5,000,000 volume per year. Few of these firms can or would sustain a training program.

2. Training programs, unless very carefully planned and controlled, will be just apprentice training. Although they will teach the trainees current practices, they will stifle curiousity and a questioning attitude, both of which are essential if the younger men are to develop greater potential than their predecessors.

3. The basic plan for most training programs makes it difficult to obtain and disseminate information on promising new developments both inside and outside the construction field. Keeping abrest of new developments is a full-time job. Then, even if the data are located, it is extremely difficult to distribute the detailed findings to the trainees at their scattered locations. Thus, to have an effective program, the company must establish a full-blown school.

It is presumptuous for educators, who have as yet made little contribution to construction, to suggest that the engineering schools can provide a better education for construction than the industry itself can. There is, however, much precedent in other fields to support this point of view. In the past, prospective lawyers "read" law in law offices, business managers started learning their functions as office boys, and accountants started as bookkeepers. Today, the colleges provide the education for professionals in these and most other fields. Certainly, as construction engineering and management become more and more professional, the colleges will take over the educational role as they have in the other areas.

Research is another area in which the colleges can make a significant contribution to the construction industry, if precedent from other disciplines can be taken as a criterion. Since to date there is little more than a stirring in this direction, only scattered proof can be offered.

To date, the construction industry lags far behind most others in expenditures for research. The 48-billion dollar building industry spends approximately 250 million dollars, or one-half of one percent of its income, for research compared with 3 percent for several others such as chemicals and electrical equipment;(9) furthermore, 95 percent of the research in building construction is concerned with manufactured products and materials. Although no data are available on research expenditures on the highway and heavy construction side, there is little evidence of formal research except in developmental work by manufacturers of machinery and equipment. Thus it must be concluded that contractors, as such, do almost nothing in the way of formal or long-range research nor do they support research by others.

Three viewpoints or attitudes of construction executives largely account for their indifference and even hostility when the question of research is raised. The first is the belief that construction procedures and operations are variable and non-repetitive and therefore cannot be analyzed scientifically. This reasoning also leads to the attitude that, even if something worthwhile were learned, it would have little value since the particular job would be completed before the findings could be put to use. The second viewpoint is that improvements in construction methods or equipment come through original ideas and inventions rather than through the painstaking step by step

analysis called for by research. There is much to justify this viewpoint, as most of the advance in methods and machinery has come in this way. The third attitude rises from the construction executive's belief that his firm already knows most of the answers and that study of its procedures will develop nothing new. Thus the only result of a study by outsiders would be to make the company's secrets available to their competitors. Several construction executives have candidly told the writers that, for the reasons given, they had little sympathy for research efforts, particularly by the colleges. They suggested that, if research were to be carried out, it should be supported by government and not by industry.

It is the writers' belief, based on serious thought and study, that research by the colleges and universities can make a real contribution to the construction industry. First, the colleges can bring to bear on construction problems the resources of all branches of knowledge, ranging through engineering, mathematics and statistics, business and management, and even including psychology and other social sciences. Second, the colleges can, and should, take a more detached and broader view towards possible approaches and solutions to problems. Almost any contractor will admit that he does not have time nor disposition for the long look. Any idea must pay off at once to be worth the effort. Finally, the research findings of colleges can be disseminated widely through teaching and publications, in contrast to today's attitude of secrecy.

Among the areas where ideas from other disciplines, coupled with research to adapt them to construction, indicate promise are the following:

1. Single industrial engineering techniques such as crew-balance studies, process chart analysis, and methods standardization. A few construction companies have made great progress in this direction. Some of them have stated privately that the savings often bring a reduction in cost of as much as 20 percent. However, they guard their methods carefully from competitors and educators alike to maintain the competitive advantage that results. It appears then, that both the development of techniques and the wider dissemination of information about existing practices offer promise.

2. Improved techniques for planning and scheduling. These could range from rather simple procedures to solutions by statistical or computer techniques in complex situations.

3. The application of statistical methods to diverse problems. These may well range from determining proper balance in equipment groups to a statistical approach to the effects of weather and climate on construction operations.

4. The application of data processing equipment, including computers, to contractor's record-keeping and computation problems.

5. The application of ideas and equipment from other fields, such as developments in automation, to construction.

6. The adaptation to construction of ideas and practices in a number of management problems such as personnel development and training, employee relations, and accident prevention, to name a few.

The list given above is far from complete. However, it does indicate that many disciplines can have ideas and techniques of value to construction. The colleges and universities, as contrasted with industry, provide the best situation for this cross-fertilization.

There are, of course, many other more traditional areas for research in construction, such as the development of and proving of new materials and products and the development and improvement of machinery and equipment. Here also an expanded research program in the colleges could be of real value to the industry.

Properly directed and programmed research for construction could do much to strengthen today's modest efforts in construction education. Income from research on a continuing basis would permit the schools to expand their staffs and to include specialists on them that they cannot now afford. A combined program of research and teaching, coupled with adequate compensation, could attract able men from the industry into teaching and thus aid in solving one of the most critical problems of the colleges. Advanced or graduate students could earn their college expenses and broaden their knowledge at the same time with work on research. At present, many of them devote this time to menial and non-learning jobs to make their way through school. In fact, money spent on suitable research works twice: once in supporting staff and students and again in the knowledge that it produces.

This statement is not an argument that colleges go all-out on research in competition with commercial testing agencies or private consultants. College research should meet the double tests: first that it strengthens the educational effort of a school and, second, that it fills a gap that cannot be closed by commercial or consulting personnel.

It seems clear, however, that properly chosen and financed research in the colleges can be of value to the construction industry in two ways. First, it can develop concepts and techniques of value to the industry; second it can strengthen the educational program of the schools which, in turn, will produce better-educated men for the industry.

Current practices and trends in education for construction

The colleges and universities have been talking of education for construction for many years. Some schools such as M.I.T. began programs slanted toward construction thirty or more years ago. Many other schools gave courses pertaining to construction before World War II.(10) Spokesmen for the industry, such as Adolph J. Ackerman,(11) pointed out the special educational needs of the construction industry and suggested changes in the traditional civil engineering curriculum to meet these needs.

Following World War II, construction education gained considerable impetus and the civil engineering departments of a number of schools began programs aimed specifically at construction. At some schools students could choose a "construction option" as contrasted with structures, hydraulics, or some other speciality. Other schools offered almost the same selection of courses as free electives but without the "option" label.(12) In almost all cases, the curriculum combined the conventional accredited civil engineering program of the school in question with some or all of the following subjects: estimating, equipment and methods, accounting, law, and labor relations. During this same period, several schools of architecture, architectural engineering or business offered programs in "building construction."(6) These programs are directed largely at home and commercial building. Discussions of them is beyond the scope of this paper.

Beginning in the early or middle 1950's, several schools expanded their offerings in construction to include a fifth year devoted in the main to developing

the business, management, and construction subjects that could not be fitted into a crowded four-year program. As should be expected, each school has chosen a pattern suited to its own organization, traditions, and faculty strength. Three of these are as follows:

1. Texas A. and M. College.(13) A joint program in civil engineering and business administration leading to BS degrees in both civil engineering and business administration.

2. Cornell University.(14) A five-year curriculum leading to a BS degree in civil engineering. Construction and management are treated as essential elements of civil engineering at the same level as technical and cultural subjects. In general, the content of the Cornell program agrees with that proposed by William A. Klinger,(5) who is one of the spokesmen on educational matters for the Associated General Contractors.

3. Stanford University.(15) A fifth-year program leading to the Master of Science in Civil Engineering-Construction. The program (See Table I) includes a series of required graduate construction courses plus a few required courses in management and technical areas. The remainder of the year is given to elective courses in management and technical subjects, selected by the student with the advice of his adviser. The philosophy of the Stanford program is that no prescribed program can fit all the many facets of construction. It is better that each individual select a program to fit his interests than to fit all to a single pattern.

To date, then, the pattern in construction education in civil engineering schools has been: First, the development at some schools of a few undergraduate construction and related courses within the framework of conventional civil engineering; second, the fifth-year programs in a handful of schools where staff strength and interest and a favorable academic climate have made this development possible. However, far too little is being done to meet the expected demands for engineers educated to fit the needs of the construction industry.

What are the prospects for more attention to construction from the engineering schools in the years close ahead? Every indication is that they are bleak; for the following reasons, among others:

1. Failure on the part of the construction industry to make its needs known to the colleges. To date, only a small group of contractors and a handful of educators have made their voices heard.

2. Failure on the part of the construction industry to support education and research in the colleges at a level even closely comparable to that supplied by other industries. In all frankness, money talks! Financial support through scholarships, fellowships, research grants and, in some cases, faculty salaries will do much to create an interest in construction on the part of college administrators.

3. The slow pace at which changes take place in the colleges. Contractors will find it difficult to believe that to change the curriculum or add a course may require several years time. Often changes must wait on the retirement of a department head or a senior professor who has an intrenched interest in a large block of student time. Again, at some schools a personality clash or rivalries within the department may prevent desirable alterations.

Changes favoring construction may prove particularly difficult to introduce because many college people do not consider that it is engineering or on a par with other subjects.

4. The trend away from professional education and towards science among engineering educators. Today, whenever possible, new appointments to engineering faculties are given to men with PhD degrees. There are few if any men in construction practice or education with PhD degrees, nor will there be many in the years immediately ahead. It follows that very few in the new generation of college professors will be professional men with construction interests. Thus the already meager interest in construction education among college faculties will fall ever farther.

5. The relatively low enrollment in civil engineering as compared with other branches of engineering and science. Under these circumstances, the colleges will be cutting down on the size of their civil engineering budgets and staffs. The pressure will be to reduce the number of courses now being given, and this will make it doubly hard to add construction subjects.

Thus, it appears clear that there are many obstacles to developing a widespread program of construction education in our colleges. Most certainly much stronger efforts must come from the construction industry than are now being exerted if much is to be accomplished in the years ahead.

CONCLUSION

This paper has attempted to face up squarely to the joint problems confronting civil engineering education and the construction industry. In summary, it has made the following points:

1. A civil engineer's answer to the question "What the construction industry should have from the engineering colleges," depends on his concept of the relationship between the construction industry and the civil engineering profession. If he considers construction as simply a business with which he must have dealings, his answer will be entirely different from his considering construction an integral and vital part of the civil engineering function. This paper is based on the latter viewpoint.

2. Civil engineers are in demand by the construction industry, are entering it in an ever increasing numbers, and are taking over much of its management. For the civil engineer who will work hard, construction offers an exciting challenge, the chance to use every part of his education, and substantial rewards for accomplishment.

3. The civil engineering profession as a whole has much to gain by strengthening its ties with construction. This can result only through the joint efforts of design engineers, contractors, and educators.

4. Education pertaining to construction merits a place at both undergraduate and graduate levels, provided it is treated professionally. It is important that all civil engineering graduates have certain minimum knowledge of construction practices and problems, while those who plan to make construction their life's work should receive additional specialized education.

5. Research on construction problems has a proper place in the colleges. Furthermore, it can make a substantial contribution both to the industry and to the colleges.

6. To date, the engineering schools have made little progress toward meeting the specialized educational needs of the construction industry. It is true that a number of schools provide some emphasis on construction at the undergraduate level and a few have organized fifth-year programs. So far, however, the overall effort has been small compared to the need and opportunity. Moreover, there are a number of obstacles in the way of greater activity, and there is little reason for optimism in the future unless attitudes change both on the part of industry and the colleges.

As of today, the engineering colleges have a golden opportunity, through education for construction, to make a substantial contribution to the industry, and to the people that construction serves. As in any important undertaking, there are many problems, and in this case, neither the industry nor the colleges have made a sincere attempt to overcome them. Only through real concern on the part of a substantial number of contractors, engineers, and educators, coupled with a generous application of industry interest and financial support, can the opportunity be made into a reality.

TABLE I

Requirements for M.S. Degree in
Civil Engineering-Construction at Stanford University

Forty-five or more quarter-units total, divided as follows:

1. Required undergraduate civil engineering courses. (Fully satisfied if the candidate has an ECPD accredited B.S. degree in civil engineering.)

2. Undergraduate construction courses (6 quarter units)

	Quarter Units
Construction Estimates and Costs	3
Construction Equipment and Methods	3

3. Core group in construction and business (15 quarter units)

Construction Administration	3
Advanced Construction Equipment and Methods	4
Concrete Construction	3
Advanced Engineering Economy (Equipment ownership and replacement)	2
Depreciation (Tax aspects of equipment ownership)	3

4. Electives in Business Management and Related Subjects (Minimum — 14 quarter units)

Construction Problems (special investigations)	3
Civil Engineering Economy (Economics of Public works)	2
Business Law — Contracts, quasi-contracts	5
Business Law — Sales, Negotiable Instruments	5
Business Law — Agency, Partnership, Corporations	5
Industrial Organization and Management	4

	Quarter Units
Time and Motion Study	4
Engineering Accounting	3 or 5
Business Economics	4
Management Accounting	4
Cost Accounting	4
Business Finance	4
Industrial Management	4
Psychological Aspects of Business	4
Industrial (Labor) Relations	4

5. Required and Elective Courses in Advanced Civil Engineering and Related Technical Subjects (Minimum 10 quarter units)

REQUIRED

Advanced Foundation Design	3
Harbor Structures	3

ELECTIVES

Structural Geology	5
Engineering Geology	3
Principles of Mining	3
Mine Plant and Equipment	4
Introduction to Electronics	3

Advanced courses in civil engineering including those in structures, soil mechanics, hydraulic engineering, and highways (50 or more quarter units from which to choose)

Courses in engineering mechanics.

Courses in mechanical, electrical, and industrial engineering.

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4. The Constructor, November 1955, p. 70.
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10. Content of Courses Pertaining to Construction, a report issued in June, 1941, by the Civil Engineering Division of the (then) Society for the Promotion of Engineering Education. M. I. Evinger of the University of Nebraska was committee chairman.

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12. See papers by R. L. Peurifoy, C. H. Oglesby, and F. H. Kellogg in Civil Engineering Bulletin of the Civil Engineering Division, American Society for Engineering Education, February 1951, pp. 2-9.

13. S. R. Wright, The Constructor, February 1957, pp. 77-78.

14. Engineering News-Record, November 7, 1957, pp. 23-25.

15. Western Construction, January 1956, pp. 72-74 and February 1958, pp. 48-49.

PROCEEDINGS PAPERS

The technical papers published in the past year are identified by number below. Technical-division sponsorship is indicated by an abbreviation at the end of each Paper Number, the symbols referring to: Air Transport (AT), City Planning (CP), Construction (CO), Engineering Mechanics (EM), Highway (HW), Hydraulics (HY), Irrigation and Drainage (IR), Pipeline (PL), Power (PO), Sanitary Engineering (SA), Soil Mechanics and Foundations (SM), Structural (ST), Surveying and Mapping (SU), and Waterways and Harbors (WW), divisions. Papers sponsored by the Department of Conditions of Practice are identified by the symbols (PP). For titles and order coupons, refer to the appropriate issue of "Civil Engineering." Beginning with Volume 82 (January 1956) papers were published in Journals of the various Technical Divisions. To locate papers in the Journals, the symbols after the paper number are followed by a numeral designating the issue of a particular Journal in which the paper appeared. For example, Paper 1859 is identified as 1859 (HY 7) which indicates that the paper is contained in the seventh issue of the Journal of the Hydraulics Division during 1958.

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FEBRUARY: 1528(HY1), 1529(PO1), 1530(HY1), 1531(HY1), 1532(HY1), 1533(SA1), 1534(SA1), 1535(SM1), 1536(SM1), 1537(SM1), 1538(PO1)[c], 1539(SA1), 1540(SA1), 1541(SA1), 1542(SA1), 1543(SA1), 1544(SM1), 1545(SM1), 1546(SM1), 1547(SM1), 1548(SM1), 1549(SM1), 1550(SM1), 1551(SM1), 1552(SM1), 1553(PO1) 1554(PO1), 1555(PO1), 1556(PO1), 1557(SA1)[c], 1558(HY1)[c], 1559(SM1)[c].

MARCH: 1560(ST2), 1561(ST2), 1562(ST2), 1563(ST2), 1564(ST2), 1565(ST2), 1566(ST2), 1567(ST2). 1568 (WW2), 1569(WW2), 1570(WW2), 1571(WW2), 1572(WW2), 1573(WW2), 1574(PL1), 1575(PL1), 1576(ST2)[c] 1577(PL1), 1578(PL1)[c], 1579(WW2)[c].

APRIL: 1580(EM2), 1581(EM2), 1582(HY2), 1583(HY2), 1584(HY2), 1585(HY2), 1586(HY2), 1587(HY2), 1588 (HY2), 1589(IR2), 1590(IR2), 1591(IR2), 1592(SA2), 1593(SU1), 1594(SU1), 1595(SU1), 1596(EM2), 1597(PO2), 1598(PO2), 1599(PO2), 1600(PO2), 1601(PO2), 1602(PO2), 1603(HY2), 1604(EM2), 1605(SU1)[c],1606(SA2), 1607(SA2), 1608(SA2), 1609(SA2), 1610(SA2), 1611(SA2), 1612(SA2), 1613(SA2), 1614(SA2)[c], 1615(IR2)[c], 1616 (HY2)[c], 1617(SU1), 1618(PO2)[c], 1619(EM2)[c], 1620(CP1).

MAY: 1621(HW2), 1622(HW2), 1623(HW2), 1624(HW2), 1625(HW2), 1626(HW2), 1627(HW2), 1628(HW2), 1629 (ST3), 1630(ST3), 1631(ST3), 1632(ST3), 1633(ST3), 1634(ST3), 1635(ST3), 1636(ST3), 1637(ST3), 1638(ST3), 1639(WW3), 1640(WW3), 1641(WW3), 1642(WW3), 1643(WW3), 1644(WW3), 1645(SM2), 1646(SM2), 1647 (SM2), 1648(SM2), 1649(SM2), 1650(SM2), 1651(HW2), 1652(HW2)[c], 1653(WW3)[c], 1654(SM2), 1655(SM2), 1656(ST3)[c], 1657(SM2)[c].

JUNE: 1658(AT1), 1659(AT1), 1660(HY3), 1661(HY3), 1662(HY3), 1663(HY3), 1664(HY3), 1665(SA3), 1666 (PL2), 1667(PL2), 1668(PL2), 1669(AT1), 1670(PO3), 1671(PO3), 1672(PO3), 1673(PL2), 1674(PL2), 1675 (PO3), 1676(PO3), 1677(SA3), 1678(SA3), 1679(SA3), 1680(SA3), 1681(SA3), 1682(SA3), 1683(PO3), 1684 (HY3), 1685(SA3), 1686(SA3), 1687(PO3), 1688(SA3)[c], 1689(PO3)[c], 1690(HY3)[c], 1691(PL2)[c].

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AUGUST: 1725(HY4), 1726(HY4), 1727(SM3), 1728(SM3), 1729(SM3), 1730(SM3), 1731(SM3), 1732(SM3), 1733 (PO4), 1734(PO4), 1735(PO4), 1736(PO4), 1737(PO4), 1738(PO4), 1739(PO4), 1740(PO4), 1741(PO4), 1742 (PO4), 1743(PO4), 1744(PO4), 1745(PO4), 1746(PO4), 1747(PO4), 1748(PO4), 1749(PO4).

SEPTEMBER: 1750(IR3), 1751(IR3), 1752(IR3), 1753(IR3), 1754(IR3), 1755(ST5), 1756(ST5), 1757(ST5), 1758(ST5), 1759(ST5), 1760(ST5), 1761(ST5), 1762(ST5), 1763(ST5), 1764(ST5), 1765(WW4), 1766(WW4), 1767(WW4), 1768(WW4), 1769(WW4), 1770(WW4), 1771(WW4), 1772(WW4), 1773(WW4), 1774(IR3), 1775 (IR3), 1776(SA5), 1777(SA5), 1778(SA5), 1779(SA5), 1780(SA5), 1781(WW4), 1782(SA5), 1783(SA5), 1784 (IR3)[c], 1785(WW4)[c], 1786(SA5)[c], 1787(ST5)[c], 1788(IR3), 1789(WW4).

OCTOBER: 1790(EM4), 1791(EM4), 1792(EM4), 1793(EM4), 1794(EM4), 1795(HW3), 1796(HW3), 1797(HW3), 1798(HW3), 1799(HW3), 1800(HW3), 1801(HW3), 1802(HW3), 1803(HW3), 1804(HW3), 1805(HW3), 1806 (HY5), 1807(HY5), 1808(HY5), 1809(HY5), 1810(HY5), 1811(HY5), 1812(SM4), 1813(SM4), 1814(ST6), 1815 (ST6), 1816(ST6), 1817(ST6), 1818(ST6), 1819(ST6), 1820(ST6), 1821(ST6), 1822(EM4), 1823(PO5), 1824 (SM4), 1825(SM4), 1826(SM4), 1827(ST6)[c], 1828(SM4)[c], 1829(HW3)[c], 1830(PO5)[c], 1831(EM4)[c], 1832(HY5)[c]

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JANUARY: 1892(AT1), 1893(AT1), 1894(EM1), 1895(EM1), 1896(EM1), 1897(EM1), 1898(EM1), 1899(HW1), 1900(HW1), 1901(HY1), 1902(HY1), 1903(HY1), 1904(HY1), 1905(PL1), 1906(PL1), 1907(PL1), 1908(PL1), 1909(ST1), 1910(ST1), 1911(ST1), 1912(ST1), 1913(ST1), 1914(ST1), 1915(ST1), 1916(AT1)[c], 1917(EM1)[c], 1918(HW1)[c], 1919(HY1)[c], 1920(PL1)[c], 1921(SA1)[c], 1922(ST1)[c], 1923(EM1), 1924(HW1), 1925(HW1), 1926 (PL1), 1927(HW1), 1928(HW1), 1929(SA1), 1930(SA1), 1931(SA1), 1932(SA1).

FEBRUARY: 1933(HY2), 1934(HY2), 1935(HY2), 1936(SM1), 1937(SM1), 1938(ST2), 1939(ST2), 1940(ST2), 1941(ST2), 1942(ST2), 1943(ST2), 1944(ST2), 1945(HY2), 1946(PO1), 1947(PO1), 1948(PO1), 1949(PO1), 1950(HY2)[c], 1951(SM1)[c], 1952(ST2)[c], 1953(PO1)[c], 1954(CO1), 1955(CO1), 1956(CO1), 1957(CO1), 1958 (CO1), 1959(CO1).

c. Discussion of several papers, grouped by divisions.

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